

0.3 to 1 c.c. (m v. to xv.); a 15-per-cent. tincture, dose 2 to 6 c.c. (fl ʒ ss.-iss. or ij.).

Henbane Seeds, though unofficial, are largely employed. They are light-brown, broadly kidney-shaped, and flattened, 1 to 1.5 mm. long and nearly as broad, and finely pitted. Thus they bear a close resemblance to stramonium seed, except in color and in their size, which is one-fourth to one-third as great. Their alkaloidal composition is about the same as of the herb, but they contain twenty-five per cent. of fixed oil, and a little resin. Since their percentage of alkaloid is a little greater, the dose of the seeds is about one-fourth or one-third smaller than that of the herb.

There are eleven species of hyoscyamus, and several of them, notably *H. album* L., have similar properties and uses to those of *H. niger*.
Henry H. Rusby.

HENNA.—Under this name the leaves of *Lawsonia inermis* L. (fam. *Lythraceae*) are extensively used in Eastern countries as a pigment for coloring the skin and hair and also as an astringent. Their use in jaundice is doubtless due to a superstition relating to their color. They contain a peculiar astringent resinous substance which has been called henotannic acid.
Henry H. Rusby.

HENPUYE.—GOUNDOU, ANAKHRÉ, GROS NEZ, DOG NOSE. Under the second, third, and fourth of these names the French writers, and under all of them except *gros nez* the English writers, describe a disease which up to the present has not been found outside of tropical or sub-tropical countries. The trouble in question consists of a peculiar form of exostosis or bony tumor, situated on each side of the nose. The growth is always bilateral, and usually symmetrical, but occasionally one side grows larger or more rapidly than the other. The exostosis is from the external surfaces of the nasal bone and the nasal process of the superior maxillary bone, with involvement of the body of the superior maxillary bone in severe cases. The trouble is confined to the bone; the nasal cavities, nasal cartilages, mouth, or orbits not being affected except mechanically by the presence or pressure of the tumor.

GEOGRAPHICAL DISTRIBUTION.—When first noticed goundou, or henpuye, was supposed to be limited to the Ivory Coast of West Africa and to the district watered by the river Comœ.¹ Since then it has been found in the neighboring territory of the Gold Coast;² and further afield at Sierra Leone (*Jour. of Trop. Med.*, ii., 145); but in every case the sufferer was a negro. But cases have since been reported of a Malay being affected in Sumatra (*Jour. of Trop. Med.*, iii., 11), a native in Southern China (*Jour. of Trop. Med.*, iii., 110), and some negroes in Jamaica, West Indies.³ The case of goundou reported from Singapore (*Jour. of Trop. Med.*, July 1st, 1901, p. 213) was probably not one of goundou at all, as the tumor was not solid but consisted of a shell of bone covering cerebral meninges. We may safely say that the disease is confined to tropical and sub-tropical countries, with a predilection for the negro race.

GENERAL DESCRIPTION AND COURSE OF THE DISEASE.—The trouble generally commences with a cold in the head followed by headaches chiefly over the frontal region; these headaches last for about a year, when a slight fullness is noticed on each side of the nose; as this swelling increases the headaches are apt to disappear. Sometimes the tumor will continue to grow for a year or two only, and sometimes it will develop slowly for many years. The overlying skin is apparently quite normal, being freely movable and quite healthy in appearance. The tumors are non-fluctuating, grow slowly and almost symmetrically with no tendency to suppurate, have an ovoid shape with the long axis outward and downward, become intensely hard, but are not as a rule painful except in wet weather. There is no tenderness on pressure. The size varies from a pea to an orange or an ostrich's egg,¹ but a pigeon's egg may be taken as an average of the dimensions attained. Of course the countenance is terribly deformed. In some cases a bloody or purulent discharge

from the nose has been observed; in others there has been neither discharge nor sore. The cartilages of the nose are not involved, nor is the nasal duct; and there is no epiphora. Sometimes the tumor will press upon the anterior nares and compress the cavities, with the result that the voice obtains a nasal twang. The orbital cavities may be similarly pressed upon, but generally the growth of the tumor causes first a squint, then the patient may have to flex his head in order to see over the tops of the tumors; and later on, the tumors becoming still larger, there is a total obstruction of vision. But the eyeball is not destroyed. In Maclaud's cases¹ the patients were free from tuberculosis and syphilis. Chalmers's cases² had all suffered from yaws.

ETIOLOGY.—The natives of the Ivory Coast believed in a divine or diabolical origin of the disease. Maclaud¹ advanced the theory that the trouble was parasitic, being due to the larvæ of some dipterous insect; but the bilateral and symmetrical nature of the complaint remain unexplained by this hypothesis. Further, for the acceptance of this theory, it would be necessary to know the particular insect or insects with their exact habitat, and to ascertain whether this insect is found in West Africa, China, Sumatra, and the West Indies. Chalmers² considers the disease the result of yaws or frambœsia, which certainly seems more plausible; he asserts that goundou follows that disease, that it is caused by the absorption of the yaws poison from the mucous membrane of the nose and is carried by the lymphatics and small vessels through the foramina in the nasal process of the superior maxilla, and that in the cases which he observed there was a sore in and some discharge from the nose. But if goundou was caused by yaws there would have been hundreds of cases reported from the West Indies alone, where yaws has been carefully studied. Strachan considers it the result of atavism;³ this theory seems the most probable of any, and, as in the somewhat similar case of the "horned men" of Africa, these bony outgrowths may be considered hereditary or at any rate characteristic of race. Of these "horned men" Macalister says "that outgrowths here may be really race characters is not to be entirely ridiculed, for the neighboring malar bone which here, according to O'Reilly's description, participates in the swelling, certainly shows certain race peculiarities, such as the bigger *Tuberositas malaris* of the Mongolians, and the *Processus marginalis*, whose race peculiarities have been pointed out by Werfer" (Bland Sutton, "Evolution and Disease," 1890, p. 197, English edition). It may be well to mention here the chief differences between goundou and the deformity of the horned men: (1) in the former the tumor is fairly parallel with the nasal bone, in the latter it is at right angles to it; (2) in goundou the exostosis is from the nasal process, in the "horned men" it is from the infraorbital ridge; (3) in goundou the malar bone is not affected, while it is apt to be involved in the latter condition.

PATHOLOGY.—The growth consists of a centre of cancellous bone, covered with a casing of hard compact bone, from which the periosteum can be very easily removed. The growth is in all probability an osteoplastic periostitis.

TREATMENT.—Iodide of potassium has been tried but without success. The only treatment is surgical. A longitudinal incision is made in the skin over the tumor, with perhaps a cross incision to allow more room, and the tumor can be removed with a saw, gouge, or bone forceps; the hemorrhage, which is slight, can generally be controlled by pressure; and under the ordinary aseptic precautions the parts unite by first intention.
R. J. E. Scott.

REFERENCES:

- ¹ Maclaud: Archives de médecine navale, tome lxxiii., p. 25.
- ² Chalmers: Lancet, London, 1900, i., p. 20.
- ³ Strachan: Brit. Med. Journ., 1894, i., p. 189.

HEREDITY.—Heredity may be defined as a correlation between the variations of characteristics in individuals related to one another by birth.

The words used as the names of phenomena are apt to

influence our conceptions of their character. This is particularly true of heredity. No doubt, most persons think of heredity as similar to the inheritance of goods and chattels. To them a son has received from his father the color of his eyes very much in the same way that he may expect to receive his seal ring or his watch. Such an idea is entirely foreign to the scientific conception of heredity, and in using the term it is necessary to keep in mind always its metaphorical character in order not to confuse the metaphor with the reality that it represents. Scientifically heredity is merely a special case of the correlation of variations.

This correlation may be *direct*, as between father or mother and son or daughter, between grandfather and grandson, etc.; or it may be *collateral*, as between brothers, sisters, brothers and sisters, uncles or aunts and nephews or nieces, between cousins, etc. In man and the higher animals inheritance is always *biparental*. That is to say, every individual has two parents; but there are cases in which there is only one parent, as in certain insects and crustacea that produce young most frequently by means of parthenogenetic eggs, and among some of the lower animals and the plants, which frequently produce new individuals by means of buds, underground shoots, etc. In such cases inheritance is *uniparental*.

Of direct inheritance there are three important types: (1) *blended inheritance*, where the child is intermediate in character between the two parents, as in stature; (2) *exclusive inheritance*, where the character of the child is like that of one parent but not like the other, if they differ, as in the color of the eyes; (3) *particulate inheritance*, where the characters of both parents appear in the child, but do not blend; for example, a pup may have spots, some of which are of the color of the mother, while others are like the coat of the sire, or a boy may have a nose like his father and eyes like his mother.

Variability.—Variation is deviation from the type, and for most statistical inquiries the type taken as the standard is the arithmetical mean of the population or group. Deviations are of two kinds, abnormal, such as the "sports" of the horticulturist, and normal variations, which may be observed in every family or other group of individuals. The normal variations are found to be distributed about the mean in a way that may be expressed by certain mathematical formulæ derived from the theory of probability and chance (see articles *Evolution and Variation*). The relations most frequently met with are represented in Fig. 2604.

The rectangles in this figure taken together form what is called a polygon of frequency, and the flowing curve is a theoretical curve of chance, or probability, that has been fitted to the polygon, which represents graphically the observed facts. Now if we plot the curves of two

sets of observations, employing units of scale of the same value in both, the differences in the forms of the curves will depend upon the number of individuals in the most frequent class, or *mode*, that is the tallest rectangle, and

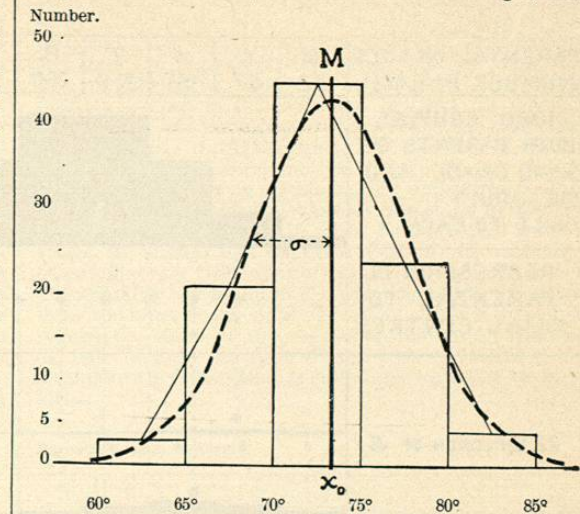


FIG. 2604.—Graphical Representation of a Series of Variations. Variation in the width of the angle at the apex of the shell in *Purpura lapillus*. M , position of the mean; σ , standard deviation.

supposing the curve to be symmetrical, upon the amount of deviation on either side of the mean. The amount of deviation, that is the *variability* of the group, is measured by what is called the *standard deviation* (the "mean error" of the mathematicians). This is obtained by multiplying the square of the deviation from the mean of each class by its frequency, adding all the results together, dividing by the total number of observations, and finding the square root of the quotient ($\sigma = \sqrt{\frac{\sum (x^2 f)}{n}}$). The Greek letter σ is used as the

symbol for this quantity. Its relation to the curve of frequency is shown at σ in Fig. 2604.

Correlation.—"Two variable organs are said to be correlated when the variation of one is accompanied on the average by more or less variation of the other, and in the same direction" (Galton, 1888). In order to determine the degree of *correlation* between two organs accurately, it is necessary to have a large number of observations and to arrange them in a "correlation table" like the one given below, Table I.

TABLE I.—CORRELATION IN THE LENGTH OF FIRST JOINT OF INDEX FINGERS OF WOMEN, RIGHT AND LEFT HANDS. (From Whitely and Pearson.)

LEFT HAND (RELATIVE CLASSES). Length of joint in inches.	RIGHT HAND (SUBJECT CLASSES).												Totals.	
	1.95 to 2.00.	2.00 to 2.05.	2.05 to 2.10.	2.10 to 2.15.	2.15 to 2.20.	2.20 to 2.25.	2.25 to 2.30.	2.30 to 2.35.	2.35 to 2.40.	2.40 to 2.45.	2.45 to 2.50.	2.50 to 2.55.		2.55 to 2.60.
1.90 to 1.95.....	1	1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3
1.95 to 2.00.....	1	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3
2.00 to 2.05.....	1.5	7.5	13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	27
2.05 to 2.10.....	1.5	2.5	12	17	3.5	1	.....	.....	.....	.....	.....	.....	.....	37.5
2.10 to 2.15.....	.....	.....	3.5	21	32	7	1	.....	.....	.....	.....	.....	.....	64.5
2.15 to 2.20.....	.....	.....	.....	4.5	38.75	35.5	9.75	1.5	.....	.....	.....	.....	.....	90
2.20 to 2.25.....	.....	.....	.....	1.5	7.25	45.25	45.25	5.25	0.5	.....	.....	.....	.....	105
2.25 to 2.30.....	.....	.....	.....	.....	1	8.25	36.5	28.5	2.25	.....	.....	.....	.....	76.5
2.30 to 2.35.....	.....	.....	.....	.....	.....	.....	7	41.25	24.5	3.25	.....	.....	.....	76
2.35 to 2.40.....	.....	.....	.....	.....	.....	.....	1	5.5	17.75	13.5	0.25	.....	.....	38
2.40 to 2.45.....	.....	.....	.....	.....	.....	.....	.....	3.5	12	6.5	0.5	.....	.....	22.5
2.45 to 2.50.....	.....	.....	.....	.....	.....	.....	.....	1	2.75	1.75	0.5	.....	.....	6
2.50 to 2.55.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	1.5
2.55 to 2.60.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.5
Totals.....	5	13	29.5	48	82.5	98	100.5	82	49.5	31.5	9.5	1	1	551

The construction of this table may be understood from a consideration of the first column of entries. Five fingers of the right hand were found in which the length of the first joint was between 1.95 and 2.00 inches. These

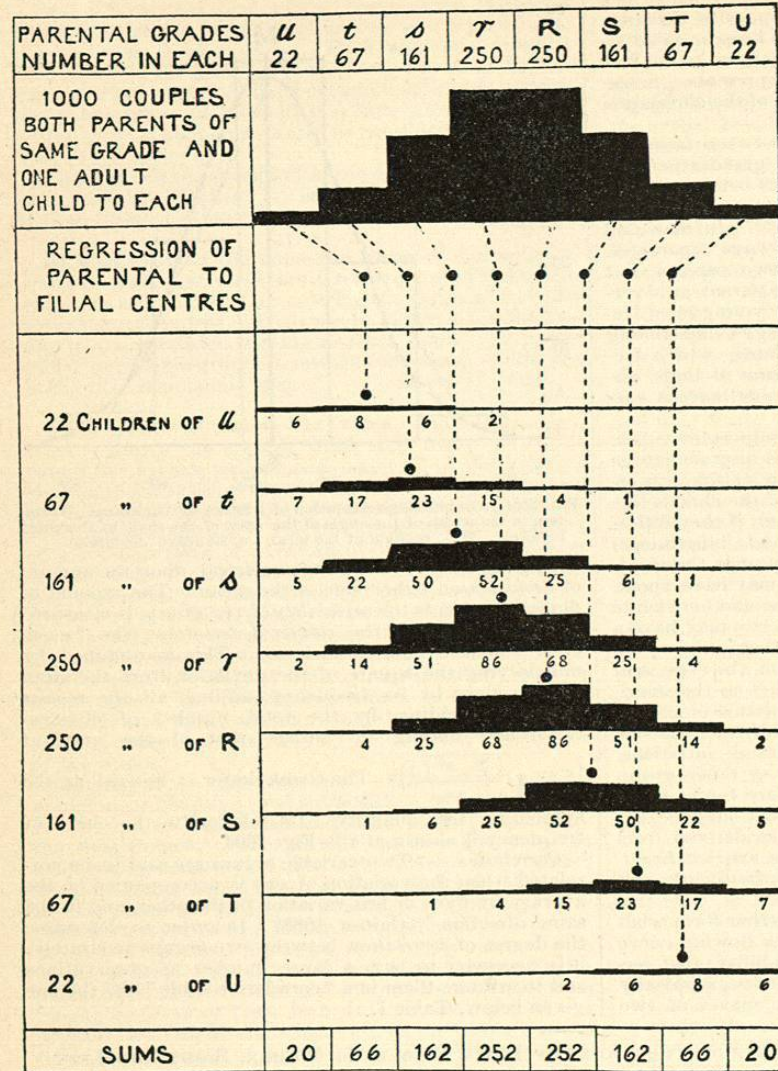


FIG. 2605.—Galton's Standard Scheme of Descent. (From Galton.)

form a "class." Of the corresponding fingers on the left hand only one was of the same length. One was shorter, 1.90 to 1.95 inches; and three were longer, one of these being exactly 2.05 inches long, was placed half in the relative class above and half below that mark. Thus the totals at the base of the columns show the number of fingers in each class of the right hand, while the figures in the columns show the number of associated fingers in each class of the left hand. The right hand is said to be the *subject* and the left hand the *relative* and each column is called an *array*. Conversely, we may, without altering the table, regard the left hand as *subject*, and the right hand as *relative*, and the arrays would then be the rows of figures, which are added up in the last column.

Now by this means we may study the correlation of any pair of organs in respect to any characteristic that permits of being expressed in quantitative terms. We may compare not only different organs or parts of the

same individual, but also any suitable characteristics of distinct individuals, provided they are related in some constant way, as for example husbands and wives, fathers and sons, brothers and sisters, etc. But fathers and sons, and brothers and sisters are related by birth, and when we study the correlation between them we are studying what is called natural inheritance.

The Phenomena of Heredity.—Some of the most important results of a long series of studies of inheritance are represented graphically in Galton's "Standard Scheme of Descent," which is reproduced in Fig. 2605. This scheme represents a supposed case in which there are a thousand couples of parents and in which each parent is mated to another of the opposite sex having relatively the same deviation from the mean in the character measured, and each couple is supposed to have one adult child. The parents are divided into eight classes having the relative frequency and deviation from the mean represented by the polygon of frequency at the top of the figure. The classes R, S, T, U, present positive deviations from the mean, and r, s, t, u, have corresponding negative deviations. The distributions of the variations in the children of each parental class are represented by the polygons below—drawn to the same scale. An attentive study of this diagram reveals many interesting things. In the first place the filial polygons are similar in form to the parental one. A dot above each filial polygon indicates the position of its mean; and the second point of interest is that the mean of any group of children does not correspond with the mean of its parents, nor with the mean of parents in general, but lies between the two. Still the mean of the children of u is much nearer the mean of u than the children of U. There is evidently a correlation between the parents and their offspring. But this is not perfect, for, while parents with negative deviations from the mean have children whose deviations on the average are negative and those with positive deviations have children who deviate on the average in the positive direction,

still in each case the mean of the children deviates from that of their parents and toward the mean of parents in general, which is probably the same as the mean of the population of which they form a sample. This tendency for the mean of the children to deviate from the type of their parents toward the type of the population in general is called *regression*. The results that follow from the laws of variability and regression in children are of considerable interest and importance. If we suppose parents of grade U to be especially gifted in some way, we see that when both parents are of this grade they may hope to have children equally gifted in the proportion of 6 to 22 or, say, two children equally gifted with themselves in a family of seven. On the other hand, if we take twenty children in grade U, only six will have parents as gifted as themselves, and two of them will be derived from very mediocre parents of grade R. Nevertheless, the chances that the exceptional

parents will produce equally exceptional children as against mediocre children are 6 to 2, while the chances of mediocre parents of grade R are 2 to 154. The reason that there are so many gifted children of relatively mediocre parents is that there are so many mediocre parents. When we add up all the children in each grade, as is done at the bottom of the scheme, we find that the mean and variability of children in general is nearly the same as of parents in general. They would have been more nearly the same if we had taken larger numbers. So, if no selection is being made, the population as a whole in one generation will be the same in character as the previous one.

For the exact study of inheritance use is made of correlation, or regression, tables similar to Table I. We have converted Galton's scheme of descent into such a table (Fig. 2606) represented graphically by placing each filial polygon as an array beneath the centre of the corresponding parental grade, or class; and adding up the filial grades at the right. In this diagram the parental deviations are measured on the horizontal scale, and the filial deviations on the vertical scale. The heights of the shaded areas represent the frequency of each parental class, and widths represent frequency in the filial classes.

The line YY occupies the position of the parental mean and the line XX the position of the filial mean. The two lines cross at right angles in the middle of the diagram. The line AB is a straight line drawn through the position of the mean (represented by a round dot) in each array and through the point of intersection of the lines XX and YY. It is called the *regression line*. In an actual regression table it would not pass through every dot, but would be placed so that the deviations of the means above and below it would balance one another as nearly as possible. Now the slope of this line may be measured by taking the ratio between the distance of any point on the line AB from the line XX and the distance from the same point to the line YY. A point three spaces to the left or right of the line YY will be two spaces below or above XX. So the slope of AB may be said to be 2 in 3, or $\frac{2}{3}$. This quantity (in this case, $\frac{2}{3}$) is called the *coefficient of regression*. It is the quantity which multiplied by the deviation of a parental class from the mean of parents will give the average deviation of its array of children from the mean of children. For example, parents of grade S deviate on the average one and one-half spaces of our scale from the mean of parents. $1\frac{1}{2} \times \frac{2}{3} = 1$, which is the deviation of the mean of the children of S from the mean of children in general. The slope of the regression line will

differ in different cases. If there were no regression, the deviations of the parental class and of the array of offspring would be the same, and the regression line would occupy the position CD. On the other hand, if there should be complete regression, the mean of the filial array would be the same as the mean of children in general, no matter how great the deviation of their parents, and then the regression line would coincide with XX. The regression line, then, may lie anywhere between the position CD where the coefficient is 1 and XX where it is 0. So the less the regression the greater the coefficient, and *vice versa*. But it is evident that the slope of the line may depend on several factors. If we should plot the parental deviations on a scale having units twice as long as in the scale of filial deviations, the slope of the line would be reduced one-half. But having equal units of scales, we should find the same result if the variability of parents were twice that of children. Now differences of variability are found in the practical study of correlations and must be taken into account. This is done if we regard the slope of the regression line as the resultant of two factors: the ratio of the two variabilities, and an unknown factor that is called the *coefficient of correlation*.

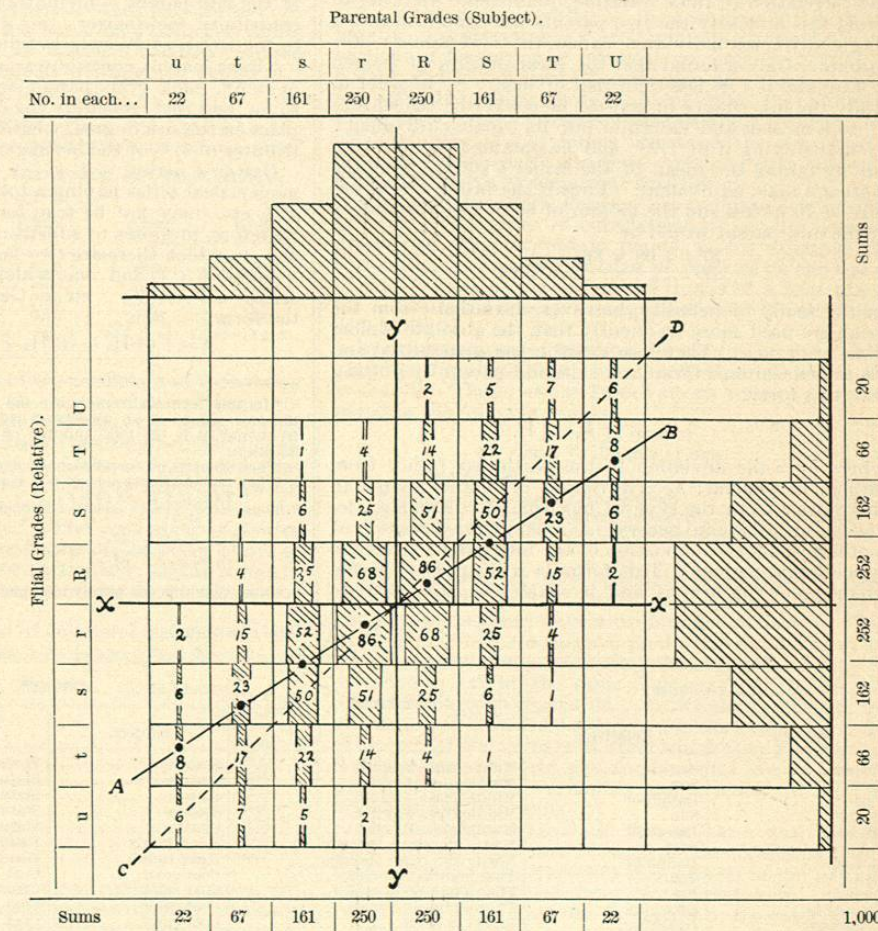


FIG. 2606.—Regression Table, Children on Parents. One thousand parents with mates of same grade and one adult child to each. (Data from Galton.)

Putting this into symbols, in this case $\frac{2}{3} = \rho \frac{\sigma_2}{\sigma_1}$, where σ_1 = standard deviation of parents, σ_2 = standard deviation of children, and ρ = coefficient of correlation. From

these considerations Pearson has derived a general formula* for calculating the value of ρ as follows:

$$\rho = \frac{\Sigma(x y f)}{n \sigma_1 \sigma_2}$$

When there is perfect correlation $\rho = 1$; when there is no correlation $\rho = 0$. In the theoretical example that we have been studying parents and children are supposed to have the same variability,—that is, $\sigma_1 = \sigma_2$. In such a case, of course, $\rho = \frac{\sigma_2}{\sigma_1}$, and the slope of the line *AB* represents the coefficient of correlation as well as that of regression.

In practice the coefficients of regression and correlation are found to be essentially the same in collateral inheritance; and also in direct inheritance, if we take into account only one parent of each couple and suppose the other to be chosen at random. The value of ρ calculated from observations in a number of such cases is given in Table II. (see below).

The Mid-Parent.—But in man and the higher animals inheritance is always biparental, and in order to study the true relations between parents and offspring it is necessary to take both parents into account. This involves the correlation of three variable quantities. In order to avoid this difficulty the two parents are combined into a single artificial individual called the *mid-parent*. For example, Galton found that the mean stature of women in England is 1.08 less than that of men. So in order to study the inheritance of stature, he converted the stature of each mother and daughter into its "male equivalent" by multiplying it by 1.08; and he obtained the mid-parent by taking the mean of the father's stature plus the mother's male equivalent. Thus if the father had a stature of 70 inches and the mother of 66 inches, the stature of the mid-parent would be

$$\frac{70 + 1.08 \times 66}{2} = 70.64$$

In the study of heredity, however, deviations from the mean are used more frequently than the absolute dimensions of organs. Therefore Pearson has generalized and simplified Galton's formula for the mid-parent by putting it in this form:

$$\frac{1}{2}(h_1 + \frac{\sigma_1}{\sigma_2} h_2) = H$$

where h_1 = the deviation in the particular father from fathers in general; h_2 = deviation of mother mated to this father from the type of mothers, σ_1 = standard deviation of fathers in general; σ_2 = standard deviation of mothers; and H = deviation of the mid-parent from the type of mid-parents. This formula will apply to measurements of any organs, and it enables one to calculate

TABLE II. (From Pearson.)

RELATIONSHIP.		Material.	ORGANS.		Coefficient of correlation ρ .
Subject.	Relative.		Subject.	Relative.	
Father	Son	Middle class English	Stature	Forearm	0.369
Father	Son	Middle class English	Stature	Stature	.396
Father	Daughter	Middle class English	Stature	Stature	.362
Mother	Son	Middle class English	Stature	Stature	.284
Mother	Daughter	Middle class English	Stature	Head index	.370
Mother	Son	North American Indians	Head index	Head index	.300
Mother	Daughter	North American Indians	Coat color	Coat color	.517
Sire	Foal	Thoroughbred horses	Coat color	Coat color	.527
Dam	Foal	Thoroughbred horses	Coat color	Coat color	.335
Grandsire	Offspring	Basset hounds	Coat color	Coat color	.134
Grandsire	Offspring	Middle class English	Stature	Stature	.391
Brother	Brother	North American Indians	Head index	Head index	.379
Brother	Brother	Thoroughbred horses	Coat color	Coat color	.623
Colt	Colt	Middle class English	Stature	Stature	.444
Sister	Sister	North American Indians	Head index	Head index	.489
Sister	Sister	Thoroughbred horses	Coat color	Coat color	.638
Filly	Filly	Middle class English	Stature	Stature	.375
Brother	Sister	North American Indians	Head index	Head index	.340
Colt	Filly	Thoroughbred horses	Coat color	Coat color	.583
Whole brethren	Whole brethren	Basset hounds	Coat color	Coat color	.508

easily either the deviation or the absolute value of the organ in the mid-parent. Having calculated the mid-parents, one may study the correlation between children and mid-parents, just as if the latter were single individuals.

The Law of Ancestral Heredity.—Now we are prepared to consider the influence of each ancestor upon the characteristics of the child. Returning to Fig. 2606, if there were no inheritance, the means of all the arrays would lie along the line *XX*; and we may think of heredity as a force tending to pull each array away from *XX* in the direction of its parental grade, that is, toward the line *CD*. Now the question is, How much of this pull is exerted by each parent, grandparent, great-grandparent, etc.?

From the study of a variety of data, Galton came to the conclusion that, of the total heritage, the mid-parent contributes one-half, the mid-grandparent one-quarter, the mid-great-grandparent one-eighth, and so on. Or, if h be the mean deviation of a given group of offspring from offspring in general and H_1, H_2, H_3, \dots be the deviations from their mid-parental means of the mid-parent, mid-grandparent, etc., of these offspring, then

$$h = \frac{1}{2} H_1 + \frac{1}{4} H_2 + \frac{1}{8} H_3 \dots \text{etc.}$$

If the mid-parent contributes one-half, each parent will contribute one-quarter. So we may state Galton's law in the words of Pearson as follows:

"Each parent contributes on an average one-quarter, or $(0.5)^2$, each grandparent one-sixteenth, or $(0.5)^4$, and so on, and that generally the occupier of each ancestral place in the n th degree, whatever be the value of n , contributes $(0.5)^{2n}$ of the heritage."

Galton's series, $\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} \dots \text{etc.} = 1$, is a geometrical series having a total of one. But the values $\frac{1}{2}, \frac{1}{4}, \dots$ etc., may not be true for all species, and Pearson, therefore, proposes to substitute the symbols $\gamma a, \gamma a^2, \gamma a^3, \dots$ etc., in which there are two factors, one constant in each generation (γ), and one which varies in a geometrical series ($a, a^2, a^3, \dots \text{etc.}$). Galton's law would now take the form

$$h = \gamma (a H_1 + a^2 H_2 + a^3 H_3 \dots \text{etc.})$$

* In this formula x and y are the deviations from their means of the two organs of an associated pair, as father and son, f is their frequency, n is the total number of pairs, and Σ is the symbol for addition.

When there is no correlation $\Sigma(x y f) = 0 \dots \rho = 0$.

When correlation is perfect $y = x$ and $\sigma_2 = \sigma_1$.

$$\text{Then } \frac{\Sigma(x y f)}{n} = \frac{\Sigma(x^2 f)}{n} = \sigma^2 \text{ and } \frac{1}{\sigma_1 \sigma_2} = \frac{1}{\sigma^2}$$

$$\therefore \frac{\Sigma(x y f)}{n \sigma_1 \sigma_2} = \frac{\sigma^2}{\sigma^2} = 1 = \rho.$$

† Note that this is a purely metaphorical expression.

Now when $\gamma(a + a^2 + a^3 \dots \text{etc.}) = 1$,

$$\frac{\gamma a}{1-a} = 1 \therefore \gamma = \frac{1-a}{a} = \frac{1}{a} - 1 \therefore a = \frac{1}{1+\gamma}$$

So we may eliminate the quantity a from the formula by substituting this value and our formula becomes:

$$h = \gamma \left(\frac{1}{1+\gamma} H_1 + \frac{1}{(1+\gamma)^2} H_2 + \frac{1}{(1+\gamma)^3} H_3 \dots \text{etc.} \right)$$

But if we wish to be very exact, we must take into account the fact that the variability of all the offspring, σ , may differ from the variability of the successive generations of mid-parents, $\sigma_1, \sigma_2, \sigma_3, \dots$, so the ratios of these standard deviations must be included in our formula, which then becomes:

$$h = \gamma \left(\frac{1}{1+\gamma} \cdot \frac{\sigma}{\sigma_1} \cdot H_1 + \frac{1}{(1+\gamma)^2} \cdot \frac{\sigma}{\sigma_2} \cdot H_2 + \frac{1}{(1+\gamma)^3} \cdot \frac{\sigma}{\sigma_3} \cdot H_3 \dots \text{etc.} \right)$$

This is the *law of ancestral heredity* as given by Pearson in its complete form. It is undoubtedly a generalization of great importance, and for a number of years to come the chief aim of a large number of scientific investigators will be to test and criticize this law. According to this theory the degree of correlation between parents and offspring will depend upon the hereditary influence represented by the symbol γ . In Galton's original formula $\gamma = 1$, very nearly. The effects of different values of γ are shown in the following table:

TABLE III.—HEREDITY—DIRECT LINE. (From Pearson.)

Offspring and—	COEFFICIENT OF CORRELATION, ρ .		
	When $\gamma = 1$.	When $\gamma = 0.9$.	When $\gamma = 2.35$.
Parent	.3000	.2851	.4000
Grandparent	.1500	.1425	.2000
Great-grandparent	.0750	.0713	.1000
Great-great-grandparent	.0375	.0356	.0500
n th order grandparent	$6 \times (\frac{1}{2})^n$	$.5702 \times (\frac{1}{2})^n$	$.8 \times (\frac{1}{2})^n$

These theoretical values of the coefficient of correlation should be compared with the values obtained from observation in Table II. From the study of "a really considerable amount of quantitative measurements of heredity" Pearson concludes that the values of the coefficient of heredity given in the first column of Table III. (when $\gamma = 1$) "seem to fit the observed facts fairly well in the case of *blended* inheritance." The coat color of horses and dogs appears to belong to one of the other types of heritage, either exclusive or particulate; and it seems to be doubtful if these types come under Pearson's law of ancestral heredity.

Table II. gives cases also of collateral inheritance, and the theoretical values, when $\gamma = 1$, are given below:

TABLE IV.—COLLATERAL HEREDITY. (From Pearson.)

Relatives.	Correlation when $\gamma = 1$.	
	Brothers.	Uncle and nephew.
Brothers	.4000	.1500
Uncle and nephew	.0825	.0750
Great-uncle and nephew	.0344	.0172
First cousins	.0344	.0082
Second cousins	.0082	.0041
Third cousins	.0041	

We see that brothers are more closely related than parent and offspring, and the correlation between first cousins is the same as that between offspring and great-grandparent.

Uniparental Inheritance.—The coefficient of correlation, or heredity, between brothers is of special interest because of its similarity to certain other correlations.

In Galton's standard scheme of descent it is supposed that both parents are of the same grade and the coefficients of regression and correlation were found to be equal and have the value $= \frac{1}{2}$. When $\gamma = 1$ this value

would be 0.6. But this is a condition that would not be met with ordinarily in nature. More often there is little or no correlation between husband and wife in the characters measured, that is, mating is at random so far as the character in question is concerned, and under these conditions the mid-parents will be less variable than the offspring; and therefore the coefficients of regression and correlation will differ. Pearson has shown that, when $\gamma = 1$, if there be no sexual selection, the coefficient of regression of offspring on mid-parents remains 0.6, but the coefficient of correlation is reduced to 0.4242. With random mating, then, the offspring will resemble their mid-parents more nearly than they will either single parent, the correlation between single parents and offspring under these conditions being $= 0.3$.

Dr. E. Warren has made an interesting comparison between these results and observations that he has made upon heredity in parthenogenesis. *Daphnia* is a small fresh-water crustacean that reproduces rapidly under favorable conditions by means of parthenogenetic eggs, thus presenting good material for the study of uniparental inheritance. From 23 individuals Warren obtained 96 young in broods of three to six, and these were allowed to grow up. He measured the length of the first joint of the second antenna of the right side in each individual and recorded the results in thousandths of the body length. Constructing a correlation table he found a coefficient of regression of offspring on mothers of 0.619 ± 0.0809 , and a coefficient of correlation of 0.466 ± 0.0539 , the offspring being more variable than the mothers. While these results are somewhat uncertain, owing to the small number of individuals measured, the resemblance between these results and those obtained with mid-parents is striking and somewhat surprising.

Very recently (1901) Pearson has published the results of twenty-two series of correlations of serially homologous organs (homotypes) in plants, as, for example, the correlation between the number of prickles on the leaves of a holly tree, of the sort on the fronds of a fern plant, etc. The result was an average coefficient of correlation of 0.4570.

In nineteen cases of fraternal correlation in the animal kingdom he obtained a mean coefficient of correlation $= 0.4479$. These results from various sources are compared in the following table:

TABLE V.—CORRELATIONS.

Relationship.	Coefficients.
Offspring and mid-parents (theoretical)	0.4242
Offspring and mothers, <i>Daphnia</i> (observed)	0.466
Homologous organs on same individual (observed)	0.4570
Brothers (observed)	0.4479

The similarity of these coefficients may be the accidental result of dissimilar causes. But Pearson has suggested that they may have a profound significance. The ova and spermatozoa that are produced so abundantly by a single individual are homologous organs, and may be expected to exhibit the same degree of correlation that other homologous organs do. As we shall see later, the characters of brothers depend to a great extent upon the characters of the germ cells from which they are derived. So there may be some one fundamental law of growth that determines the variability and heredity alike of individuals and of organs.

Exclusive Inheritance.—So far we have dealt chiefly with heritages that are blended in the offspring. But there are some characteristics that appear in the individual child as if derived from one parent only. Galton found such to be the case in regard to the color of the eyes. If one parent have dark eyes and the other light eyes, the eyes of each child will be either light or dark, seldom intermediate in color. The laws governing this form of inheritance are so uncertain at the present time that they need not be considered in this article.

Particulate Inheritance.—Every one will recall instances of particulate inheritance. It is especially well shown when individuals of two races are crossed. The writer has in mind a family in which the father was a European